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Flexible Manufacturing Systems, Related Technologies

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Wuhan Heavy Machine-Tool Institute R&D Described

90FE0074A Beijing JICHUANG [MACHINE TOOLS] in Chinese No 2, Feb 90 pp 6-7

[Article by Yu Shengjun [0080 5168 6511] of the Wuhan Heavy Machine-Tool Institute; edited by Chen Di [7115 6611]]

[Excerpt] The main products of the Wuhan Heavy Machine-Tool Institute are heavy and super-heavy machine tools. The institute adheres to the policy of manufacturing products of all sizes and developing high-quality and medium-quality products simultaneously. To date the institute has developed more than 130 products grouped into 10 major categories and 25 series. Among these, 62 items (47.7 percent of the total) are numerically controlled (NC) machine tools.

In the last 30 years the institute has made three technological advances, and there are plans to make one more technological advance in 5 years to develop machining centers (MC), flexible machining cells (FMC) and flexible manufacturing systems (FMS). In the meantime, efforts will be made to improve the functions of the NC machine tools, to develop NC machine tools for manufacturing heavy molds, and to develop the badly needed super-heavy NC machine tools. The institute will continue to cooperate with the Schiess Company of the FRG and to expand the original four series into 23 series totaling 86 products. In addition, the institute also collaborates with the [FRG's] Wotan Company in the manufacturing of the RAPID series boring and milling machines.

In the next 5 years the Wuhan Heavy Machine-Tool Institute will develop 54 new products on their own and 23 serialized products in cooperation with others. All these products will be NC heavy machine tools, MC's and FMC's. [passage omitted]

Beijing Machine-Tool Institute, JCS Group R&D Described

90FE0074B Beijing JICHUANG [MACHINE TOOLS] in Chinese No 2, Feb 90 pp 8-12

[Article by the Technology Office, Beijing Machine-Tool Institute; edited by Chen Di [7115 6611]]

[Text] (Note—JCS is an acronym for the Beijing Machine-Tool Institute in Chinese Pinyin (Ji Chuang Suo). The JCS Group consists of 13 units including the Beijing Machine-Tool Institute.)

The Second Chinese Machine Tool and Instruments Expo was conducted in the spirit of "letting science and technology be the guide, letting quality be the main issue, and rebuilding the machine-building and electronics industry." As a member of the Chinese Association of Machine Tool Industry, we congratulate the opening of the Expo and wish it great success.

The mission of the Beijing Machine-Tool Institute of the Ministry of Machine-Building and Electronics Industry (MMEI) has always been centered around the three fundamentals (fundamental technology, elements, and material), high-efficiency automation and high precision, and special manufacturing technology. In addition to research and development, the institute has also served the industry in terms of problem solving, consulting, organization and service. In the past 2 years, under the national policy of reform and openness, the institute has proposed to combine technology and economy, systematize the management and operation, integrate the organizational form, and internationalize the mode of business operation. Based on the needs of the machine and electronics industry, the institute will steadily move the technology forward. Encouraging results have been obtained in machine and electronics integration, super-precision engineering, laser manufacturing technology, and computer software. A number of projects in the national Seventh 5-Year Plan have been accomplished on schedule. A considerable effort has been devoted to the rapid commercialization of research results and good economic benefits have been obtained. Based on the high-tech results and improved coordination with sister units, the institute developed the JCS Group and enlarged the scope of technical and business exchanges in international cooperation. To mark the institute's participation in the Second Chinese Machine Tool and Instruments Expo, we hereby introduce some of the major products of the JCS Group.

Newly Developed Machine Tools

In the past the Beijing Machine-Tool Institute has developed a number of numerically controlled (NC) machine tools, machining centers (MC's) and flexible machining cells (FMC's). In the last 2 years, several new MC's have been developed for the international market. Examples are upright machining centers RE5020 and RE3020. The RE5020 machines are being exported to the United States and the RE3020 models are being manufactured by the Fourth Machine Tool Plant in Tianjin (a member of the JCS Group) and the Hanchuan Machine Tool Plant (in cooperation with the JCS Group). Machines shown at the Expo include: 1) The NC JCS-041 copying MC. This machine is based on the RE5020 model and equipped with the Italian Fidia CNC12 numerically controlled copying system. This machine has a high-efficiency copying cycle and may be used in the manufacture of high-precision molds and parts for automobiles, aircraft, textile machines and military parts. It is capable of coordinating measurement and recording, 3-D tool radius compensation, and scaling for three independent regions. 2) The TH6363 horizontal MC. This model is produced by the Beijing Machine-Tool Institute and the Tianjin No 1 Machine-Tool Plant, a member of the JCS Group. The bench dimensions are 630 x 680 mm and the machine is equipped with a Fanuc-Besk 6ME system. The settability is +/-0.01/300 mm and the repeatability is +/-5 μm. The accuracy of the NC turntable is 90° +/- 4", and the arbitrary division is

+/-10". The machine has an exchangeable dual workbench and the customer may specify either 40 or 60 cutters in the tool magazine. The model may be equipped with a zeroing transducer and may be used in a flexible manufacturing system (FMS). 3) The KT1300V, KT1400V, and KT1500V upright MC's produced jointly by the Beijing Machine-Tool Institute and the K&T Company of the United States. The main shaft power is 7.5/5.5 kW and the speed is 5,000 rpm. The workbench dimensions of the KT1300V system are 420 x 720 mm. The movement speed is as high as 12 m/min and the tool-magazine capacity is 24. The new design of the mechanical arm makes use of a cam mechanism that allows the mechanical arm to move rapidly, with a cutter-replacement time of only 2.5 seconds. The KT1300V system has been accepted by customers and is being marketed in the United States. 4) The CKA6140A NC lathe is a new product of the Wuhan No 3 Machine Tool Plant, a member of the JCS Group. This system is equipped with an American GE MTC-1T NC system and AC servo driver system. The control system is compatible with a number of languages and has a menu-style-dialogue data input feature. 5) The model GJR-G joint-type industrial robot developed by the Beijing Machine-Tool Institute 2 years ago has recently been deployed for arc welding. These robots are now operating on the welding lines of the Tianjin No 2 Bicycle Plant.

New advances in precision machining and machine tool technique include: 1) To satisfy the needs of the high-tech industries, a model JCS-035 high-precision lathe was developed. This new machine was developed on the basis of a high-precision machine technology that received a first prize at the National Invention Awards. It may be used in the machining of inner and outer spherical surfaces, circular cylindrical surfaces, and planar surfaces. It may also be used in drilling, milling, and threading of various nonspherical bodies of revolution. This machine tool can be used not only on nonferrous metals but also on ferrous metals. The main shaft uses an aerostatic bearing; the lateral jump is only 0.05 micron. The machine is equipped with a Fanuc-Besk 6M CNC system, the maximum machining diameter is 250 mm, and the maximum workpiece length is 500 mm. The precision for machining aluminum cylinders is 0.27 micron in roundness, and Ra 0.05 micron in roughness. In machining steel cylinders, the precision is 0.34 micron in roundness and Ra 0.23 micron in roughness. Since the machine has already been delivered to the customer, only photos and machined samples were displayed at the Expo. 2) The model JCS-026 roundness gauges developed by the Beijing Machine-Tool Institute using ultra-precision engineering technology are now in mass production. On display at the Expo were newly developed JCS-042 high-precision cylindricity gauges for measuring cylindricity, roundness and concentricity. This gauge is a precision instrument that ensures the quality of machined parts. 3) The CLZ1186 is a three-axis measurement machine developed by the Beijing Machine-Tool Institute using the new pneumatic suspension technology. With technology developed at the Beijing Institute and making use of granite available at Putian in Fujian Province, the Jingpu Precision Machine Company in Fujian Province has test-produced CLZ1086 three-axis measurement machines. The range of the three axes are 1,000 mm, 800 mm, and 600 mm, respectively. The machine is equipped with a British Renishaw probe and computer data processing and printing devices. This machine has been listed under the first batch of national "Torch Plan" projects and its developers are now accepting orders from foreign customers. The Qinchuan Machine Tool Plant (a partner of the JCS Group) displayed a model YC7232A worm shaft teeth-grinding wheel with an operation range of 1-6 mm, an external diameter of 20-320 mm, and a maximum helical angle of +/-45°. It is three to five times more efficient than the conical teeth-grinding wheel, the machine accuracy can reach the fifth level, and the price is only one-fourth that of an imported unit. This machine is urgently needed in the machine-tool, defense, automobile and textile industries and can be used as a substitute for imported units. The machine has been used by customers with good results. In order to meet the need for internally centering integral-key-shaft [i.e., spline-shaft] technology, the Hanjiang Machine Tool Plant (one of our partners) displayed a model MM8612 precision integral key grinding machine that they have developed. This grinder is used for the machining of integral key shafts or broach cutters with triangular or rectangular cross-sections. The Hanjiang Plant also produces the model TH6350 horizontal MC that we have transferred to them.

In the area of special machining technology, our institute has recently developed the following equipment: 1) JCS-034 NC laser cutter. This machine was developed jointly by the Beijing Institute and the Spark Group of Yugoslavia. The main frame is of the planer design, the workbench dimensions are 2,000 x 1,000 mm, the laser power is 600 W, the maximum machinable thickness is 6 mm, the kerf is 0.15 mm, and the NC system is a Fanuc-Besk 6 automatic controller. One copy has been delivered to Yugoslavia for field use. 2) JCS-033 NC laser heat-treatment machine. This machine is controlled by a Fanuc-Besk numerical controller and uses a 1,500-W laser. The machine is used mainly for inducing phase change at the surface of metal parts, case hardening, laser coating, and laser alloying of plates, strips, axles, cladding, and boxes. The machine is versatile and easy to operate. In addition to the laser heat-treatment machine, treated parts such as cylinder sleeves, couplers, and gears were also on display. The exhibit showed a variety of part surface locations hardened by laser. 3) DX45NC numerically controlled precision electric-spark shaping machine. this is a new machine tool imported from the Japax Company in Japan. It is equipped with the newly developed NC JAPT32A electric-spark machining system and the FE50A pulse source for the machining of mirror surfaces. It is capable of three-axis parallel control and, in addition to the NC

function, it permits five self-alignment-of-electrode configurations, has 11 manual control modes, three adaptive functions and implements machining-standards searches. The operation is simple and reliable and the machine is particularly suited for the machining of multielectrodes and multi-cavities. This machine represents an advanced modern high-efficiency machine tool. 4) The DKQ7132 z-axis NC electric-spark shaping machine. This is a new product developed to satisfy the needs of customers. It may be used for precision machining of molds and for machining holes 0.1 mm in diameter or greater and slots 0.2 mm or greater. It can be used in the cutting of hard alloys or for the removal of broken tools in parts. This machine uses a step motor and a microprocessor to realize the servo control of the z-axis. The sensitivity and precision are high and the operation is reliable. 5) The general-purpose DKS732 z-axis NC high-speed electric-spark machine for small holes. The machining speed may reach 20 to 30 mm per minute, the hole diameter range is 0.4 to 3 mm, the length-to-diameter ratio may reach 100, and the surface finish is Ra 1.6 microns. The machine can be used on electrically conducting materials and high-melting-point alloys for the processing of machine parts. It can also be used with wires to machine holes. 6) The Hanjiang Machine Tool Plant exhibited its DK7725 NC line cutter and wide bench PMT3570 precision surface grinding machine. 7) The model MK7625 precision NC line cutting machine. This machine was developed by the Beijing Institute and produced by the Wuhan Machine Tool Plant, a member of the JCS Group. It is equipped with a four-coordinate geared control system for automatic control. It has a slow-moving wire, diamond guides, and a sloped cutting mechanism. The working medium is de-ionized water and the operation is reliable. The machine may be equipped with the thermal deformation random compensation device developed by the Beijing Institute. The accuracy of a cut is +/-5 microns, the accuracy for machining holes is +/-5 microns, and the machined surface finish is Ra 1.6 microns. The NC system is full-featured, with magnetic tape drive, paper-tape input, paper puncher, printer, alpha-numeric CRT display, man-machine-dialogue automatic programming, sequence number display, X-Y-U-V coordinate display, malfunction display, and graphical tracking display. The machine is suitable for producing precision cold-dies, powder-metallurgy dies, profile-board shapers and cutters, and special parts. Also on display from the Wuhan Machine Tool Plant is their newly developed MK6430 NC hobbing cutter grinder for grinding DIN-AA hobbing cutters.

Numerical Control System

The dominating trend and direction for advancement in the development of machine technology today is "mechatronics"—the integration of mechanical and electrical systems. The NC system has become a major component of modern machine tools and is no longer an accessory. It may be said that a machine tool is not a modern machine tool if it does not have an NC system. The Beijing Machine-Tool Institute imported the Fanuc NC technology in the early 1980's and was able to master the technology and begin small-batch production soon after that. Over the years 1,600 NC systems and 5,600 servomotors and controllers and 630 main-shaft governor motors and controllers have been produced. Although these were just drops in a bucket for the needs of the entire profession, they nevertheless did make their contribution to the advance of the technology. Of the products made by the Beijing Machine-Tool Institute, there are the imported Fanuc 5, 7, 3, and 6 series and systems developed in-house in recent years, including the BS01 point-position NC system suitable for remodeled lathes, the BS02 single-coordinate system suitable for drill presses and rotating work platforms, and the BS03 two-coordinate system for full-feature lathe control. The BS04 three-coordinate system is a full-feature general-purpose standard for machining centers, mills, lathes, grinders and other machine tools with profile control. The BS04G displayed in the exhibits has three axes and two link gears and is suitable for high-precision outer-radius grinding. The BS06 six-coordinate full-function system uses a high-speed microprocessor, LSI application-specific chip and magnetic bubble memory; the system is highly reliable and has a good performance-to-cost ratio. The BS06M and BS06MF systems were featured in the exhibits; the former has six axes and five link gears and is suitable for advanced MC's and millers, and the latter can be used in FMC's to satisfy computer-assisted management in the loading and unloading of parts to achieve a certain level of flexible automated continuous production. In addition, the Beijing Institute has also recently cooperated with the Fanuc Company of Japan in developing the Besk-Fanuc series O Mate E-3 high-precision, three-axis full-function CNC system for lathes, millers and MC's. This system is highly integrated, compact and advanced. The machine servo system developed and produced by the Beijing Machine-Tool Institute includes a complete B4 to FB25 series with a power range of 0.4 to 2.5 kW; the complete series (No 3 to 15) of main-shaft motor and controllers covers an output power of 3.7 to 15 kW.

Systemization of Electromechanical Machine Tools and Parts

It is widely known that there are four ways to improve quality, lower costs, and adapt to the market: 1) Mass produce and automate, 2) specialize, 3) coordinate and complement, and 4) use flexible production. To achieve these four goals, we must assort, complement, and specialize the production of parts. This is also the spirit of the "one-work, three-promote" policy pronounced by MMEI to work on the fundamentals and to promote independent development ability, to promote the combination of mechanical and electronics technology, and to promote the commercialization of new technologies and research results. In addition to the NC systems, the Beijing Institute has also embarked on a number of tasks on assortment and complementation and parts development. The following results were also displayed at the exhibit.

(1) The JDT-Z40-120-JT50 and JDT-Z40-120-JT45 precision automatic fine-adjustment conical handle boring head, and the JDT-S20-120-JT45 precision manual fine-adjustment conical handle boring head. These items can be used in the automated production of MC's and NC machine tools. They may be operated manually or automatically, and are capable of automatically compensating for radius errors due to worn cutters or other reasons. With a minimum adjustment less than 1 micron, these items may replace the floating boring cutter in producing holes of even higher precision. When equipped with automatic monitoring and control devices, the operation may be totally free from human intervention and the precision of the machined holes may reach level 7. These boring heads are being produced by the Tianjin Machine Tool Parts Plant, a member of the JCS Group. Other products from the Tianjin plant include the TSG82 tool system for MC's and NC boring millers; this system will permit planar and groove milling, drilling, reaming, and threading. The Tianjin plant also displayed their TMG10 modularized tool system for boring millers. Using different modules, different cutters for MC's may be assembled. The assembly is rapid, rigid and reliable. Also on display from the Tianjin plant are composite boring cutter holders, a Morse cone holder, and a reverse drill-bit holder. The Tianjin No 2 Machine-Tool Parts Plant, another member of the JCS Group, showed layout tools to be used with cutters, including combinational structures, fixed structures and movable cutter holders with capacities of 160 and 32, and for No 40, 45, and 50 taper. Also shown were cabinets for 45 cutter shanks and carriers for 24 cutters. The Tianjin Institute of Machine Tool Research also displayed their cutter-shank clips and clip trays.

(2) Also on display by the Beijing Institute were JZ-D three-way trigger probes and measurement controls for cutter alignment in MC's and JZ-C three-way trigger probes and measurement controls for measuring the workpiece. In addition, there were also JP-D probes and controllers for cutter alignment on NC lathes and JP-C probes and controllers for measuring the workpiece. These measurement systems allow NC lathes equipped with Fanuc-6 and -11 systems to perform automatic measurements on the cutter and the workpiece in the machining cycle, and to issue warning signals and compensating signals to ensure good quality of the machined products. (Fanuc-3 systems only require a special module that we have developed.) These systems contain software for measuring typical surface profiles and for eliminating errors. The accuracy for resettability is +/-1 μm and the measurement accuracy is better than +−5 μm when the systems are used on machine tools.

On display at the exhibits were high-precision grating scales [i.e., instruments], extended grating scales, and SX041, SX042, and SX043 grating digital-display systems. The accuracy of the grating scales is +/-2 μm/m, the grating spacings are in the 0.02-to-0.04-mm range, and the length is up to 1,200 mm. The scales are equipped with absolute-zero and multiple-absolute-zero functions and may be used on high-precision machine tools, NC machines, other equipment, meters and other measurement devices. To extend the length of the grating scales, several scales may be joined in the housing according to the principle of Moll fringes; the extended scales can satisfy the needs for precision measurements on medium and large-size machines. The digital displays make use of LSI circuits and hence are compact and reliable. The BCD [binary coded decimal] output of the digital display may be connected to computers and NC systems. The serial models include single-coordinate, double-coordinate, and triple-coordinate types and are already in mass production and available on the market. Another displacement measurement device on display is the FCS1 magnetic-grid transducer and the WCS1 magnetic-grid digital-display system. Its advantages are high reliability, low cost, a multi-coordinate display, and ease of use. It has D/R and 1N/M switching functions and attachments are available based on the customer's needs.

The Tianjin Machine Tool and Optical Instruments Plant, a member of the JCS Group, showed their DDSA digital multi-position tool setter and the DDSII external optical cutter alignment device. Also on display from the Tianjin plant were the JGA laser parallelism micrometer, JTP4 optical divider, TC1 cam probe and the GZ40W universal optical turntable.

(3) The auxiliary ball screw is a key element in NC machines. The Beijing Institute was the first to develop this device and has been providing a variety of models. On display at this exhibit were level-C auxiliary ball screws in the CD, CB and FCN series. The newly developed ball screw with long travel is one of the national priority projects and is a high-tech transmission component developed in the United States and in Japan in the early 1980's. The special feature of this device is the high feed speed (15-60 m/min). The model developed by the Beijing Institute is a first in China and has been applied to new products such as the GJR-G1 welding robot, the hot-press molding machines of the Beijing and the Shanghai Tire Plants, and the automatic rail gauge measurement system. Results of the application show that it can replace imports. The long-travel auxiliary ball screws developed by the Beijing Institute include models C3232, C4025, and C4032; they are in small-batch production for customer use. They may also be used in MC's, NC automatic plotters, NC high-speed presses, radar locators, and space satellite telescopes. Also displayed was the standard ball screw developed by the Jining Ball Screw Plant, a member of the JCS Group. The Jining plant can supply ball screws of 20 to 80 mm diameter and 500 to 1,500 mm length. They also showed their main-shaft and trapezoidal screw products.

The electromagnetic clutch and brake are important components in the electromechanical integration of machine tools. In particular, the monolithic electromagnetic clutch and clutch set, and power-loss brake, are monolithic, dry devices without slip rings; they have therefore the advantages of simple structure, fast

response, long life, and high reliability. In addition to machine tools, other applications in electrical appliances are also prevalent. The Hefei Clutch Plant in Anhui Province, also a member of the JCS Group, displayed their newly developed electromagnetic clutch. In the last 3 years, the Hefei plant developed a total of 10 base models (including modified models) and 108 different products.

The DGS series grinding wheel and diamond wheel are products developed by the Beijing Institute to meet the urgent needs of customers. They are used in worm-gear grinders and other fine shaping grinding wheels. The DGS wheels are compatible with the Swiss Reishauer NZA, AZA and AM worm-gear teeth grinders. The DGS-I shaping wheel is compatible with the Hungarian FKA-326 and FKP-326-10 worm-gear grinding wheel. They consist of two single-cone diamond rollers and may replace large grain diamond tool-shaping grinders. The modulus is m0.5-6mm and the pressure angle is 20°, 14.5°, or other special angles. The teeth shape accuracy obtained with these grinders may reach level 4 in the JB118-83 standard, the teeth surface roughness can reach Ra 0.4-0.8 μm, the shaping efficiency is three to five times greater than that of diamond cutters and the cost is less than one-half that of diamond wheels. The DGS-II single-roller shaping wheel may be used conveniently on conventional grinding wheels and thread grinders. The diamond wheel is a grinding device with a single conic diamond roller; it is used mainly with DGS, DGS-I and the Swiss SPA shaping devices and it may also be used for the grinding of worm-gear wheels. In addition, we have also shaping wheels with inner gears and other diamond wheels. These devices and the diamond wheel have been successfully used by the Machine Tool Plants No 1 and No 3 in Shenyang, the Chinese-Czechoslovakia Friendship Plant, the Jinan No 1 Machine Tool Plant, the Shashi Gear Plant, the Jinwei Textile Plant, the Astronautics Plant No 230 and the No 2 Automobile Gear Plant.

Among the mechanical components displayed by the Beijing Institute were the QDY15-series explosion-proof, electric liquid servo valve. It features bipolar amplification, flow control, small volume, and a stable operating point; it is especially suitable for explosion-proof processes such as spray painting. We have applied it to robots used for spray painting.

A digitally positioned compressed-air-driven feeding table is driven by a digitally positioned piston and may be used to achieve any feeding with an accuracy of +/-0.5 mm; it is suitable for feeding the workbench or the sheet stock. The Shanghai No 3 Hydraulic Press Component Plant, a member of the JCS Group, showed its QGF1 gas/liquid pressure booster, ZH80-150 gas/liquid pressure converter, QGD50 precision gas/hydraulic pressure governor, 25Dd12-98 double-throw, five-path slide valve, low-power electromagnetic valve, magnetic cylinder without piston rod, KLJA unidirectional flow valve, and Q2LJW flow-processing coupler. Most of these are national priority projects.

Also displayed by the Beijing Institute were the GBW-1 infrared fiber-optic colorimetric thermometer (a new type of optical-electrical-computerized integrated high-tech thermometer). This device is suitable for measuring temperatures in harsh environments such as induction heating or laser heat treatment. It can withstand a high temperature, store data at a high speed and has a small interchangeable probe. The artificial granite machine bed is an application of a new material in machine building. Its damping is six times higher than that of cast iron, its heat capacity is large, and it is stable and corrosion resistant. Using artificial granites, beds for high-precision grinding machines, high-speed lathes, electrical machines, and other special machines may be built with improved dynamic characteristics and machining accuracy. An MPM precision planar grinding machine was on exhibit at the Expo. The Beijing Institute also displayed cast parts made of casting resin. The smooth surface finish is popular among users.

Computer Software Technology

The national priority projects conducted at the Beijing Institute also include the development of CAD systems for the machine tool industry. In cooperation with Dalian Science and Engineering University, the Hefei Polytechnical University, and the Beijing College of Machine Industry Management, the Beijing Institute of Machine Tools has developed a series of extensive software for industry use. These software products include:

(1) HZTCAD—A micromachine intelligent CAD for axially symmetric machine parts. This software package makes use of the principle of elemental combination and continuously performs arbitrary shape designs by combining the menu items provided by the software to establish a data bank. The system can perform automatic query, automatic selection of graph paper size, rational layout of the graph, and establish a rule bank for dimensional scaling. All the dimensional scaling is performed automatically using artificial intelligence.

(2) ZZCAD—A CAD system designed for the main transmission system and the main shaft. This software package includes the entire design process of the main transmission system and the main axle. It includes design and selection, performance analysis and optimization calculation, graphics and tabulation modules. The system is based on an icon bank, and performs parameter graphing and alternate design to ensure high efficiency and versatility. It is useful for the design of the main transmission system of MC's and NC lathes. It is easy to use and is state-of-the-art.

(3) JCS-PCB—This is a CAD software package for printed circuit boards. The user needs to provide only the board description and the wiring table source documents and the software will automatically lay out the wiring and generate the data document. The data document then automatically converts to AutoCAD diagrams, which can then be edited on the screen until the user is satisfied. After modification, the diagrams are

plotted by a plotter, photographed for printing, or automatically becomes the numerical machining document to be used by an optical plotter.

(4) CK7815 CAD/CAM integrated system—Using dialogue mode on an IBM microcomputer, the necessary geometric and machining parameters are entered to generate the NC codes needed by the machine. Through long-distance communications, the codes are transmitted directly into the NC module of the machine to produce axially symmetric parts that meet the spec. The software package has five parts: CAD for axially symmetric parts, CAPP [computer-aided process planning], automatic graphics programming, cutter locus simulation, and NC signal communication. CAD and CAPP have artificial intelligence capabilities.

(5) Machine-bed thermal error real-time compensation system—This system was developed by the Beijing Institute based on systematic studies of the thermal deformation of machine beds. The system is capable of displacement compensation for three connected coordinates, including the automatic compensation of line displacement and cutter-shank angular displacement. By measuring the actual temperature during machining, the thermal displacement may be treated in a nonlinear manner to improve the accuracy of the compensation. The two-cone and three-cone thermal error compensation boards developed by the Beijing Institute may be plugged directly into the NC module and connected to the system; no other special devices are needed. These devices have now been successfully used on lathes, linear cutting electric machine beds, and upright MC's.

(6) Linear motion uniformity measurement system and (7) transmission accuracy measurement system: Both are computer software developed using CAT technology. With measurement transducers and data processing microcomputers, the machine performance test results may be accurately measured and quantitatively analyzed. The software is easy to use and highly efficient. These software products have been put into practical use at the Machine Test Center.

Additional developments are (8) CAD for outrigger type parts, (9) CAD for machine-bed guide tracks, (10) CAD for hydraulic systems, (11) CAD for gas-driven systems, (12) CAD for clamp sets, (13) CBS program—software package for designing and computing feed and servo, (14) software package for testing the static characteristics of machine-bed structure and for improving and analyzing the structure, and (15) programs for modular space vector analysis. All the above software is available to sister institutes.

CHIMA'90 International Fair Profiled

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[Article by Chen Di [7115 6611]; edited by Song Yejun [1345 2814 6874]]

[Text] The Second Chinese Machine Tools and Instruments Expo (known as CHIMA'90) followed the goal set by Zou Jiahua, member of the State Council and director of the State Planning Commission, namely, provide advanced technology, systems of equipment, and good service for domestic and foreign users. CHIMA'90 combined exhibition and sales and served a multiple function. In order to realize the three objectives of 1) advancing technology, 2) promoting domestic and foreign sales, and 3) guiding the supply and demand of the market, CHIMA'90 reviewed the current economic situation, combined the needs in the domestic and foreign markets, organized the exhibition of a large number of high-tech and marketable products and displayed the recent achievements of the machine tools industry, and the service and production capability. In a time of consolidation and deepening reform, CHIMA'90 provided a good opportunity for promoting exports, self-improvement, and participation in international competition.

The exhibition area of CHIMA'90 was 16,000 m^2, and the exhibition platform area was 6,500 m^2, more than those in the first expo. Products of 454 participating units were displayed in the No 4, 5, and 8 buildings of the Beijing International Exhibition Center. Each building had its own theme. In building 8A, the JCS Group showed their capabilities in scientific research, development and production. The newest products of Wuhan Heavy Machinery Plant, Kunming Machine Tools Plant, and the Beijing Machine Tools Plant No 1 were all on display in building 8A. In building 8B, cast parts were on display, together with products of the Shanghai Machine Tools Plant. In building No 5, the China Machine Tools Corporation and the Electric Machining Society each displayed systems of automobile machining equipment and electro-machining facilities. In building No 4 the newest numerically controlled (NC) equipment and attachments were on display. On both sides inside the entrance to buildings No 4 and 5, there were exhibits of export companies to facilitate export business and cooperative production negotiations. In order to combine exhibition and sales in the two markets, units participating in CHIMA'90 have all set up meeting rooms and the reception group of this international fair provided enthusiastic service to the customers.

Since the November issue of last year, we have reported the organization of CHIMA'90. In the February issue of this year, we reported the exhibition items of the JCS Group and the Shanghai Machine Tools Plant. This article will be a continuation of the previous articles and is intended to provide the readers with some introductory reference material.

In this international fair, a total of 226 metal cutting machines were on display, 85 of them (37.6 percent) were NC machine tools. There were 20 machining centers (MC's) and flexible machining cells (FMC's), accounting for 23.5 percent of the NC machines. There were 67 lathes (26 NC lathes), 23 millers (six NC

millers), 37 grinding machines (five NC grinders), 16 drills (two NC drills), one boring machine, 33 electromachining tools (including 23 NC models), 10 saws (one NC saw), nine modular machine tools (three NC machines), and eight gear-processing machines (three high-precision units and four high-speed units). In addition, there were also 27 NC systems, three industrial robots, servo systems, auxiliary machines, machine attachments, cutter gauges, measurement devices, polishing compounds, and electrical devices for machine tools. In the space below we shall describe the unique features of the display items.

I. Develop Different Classes of NC Machines To Meet Different Customer Needs

As the reform and openness take root, the import and digestion of advanced technology and secondary development have permitted the quality of Chinese electromechanical products to gradually approach that of foreign countries. In order to gain an equitable "starting point" in the international competition, every outward-looking enterprise leader is paying attention to the production of modern products using modern industrial facilities. But the machinery manufacture of a country is made up of different manufacturing plants with different requirements. An exhibition of machine tools of different level can therefore provide the customers with some choices.

1. MC's and FMC's

Of the NC machines displayed in CHIMA'90, 20 were machining centers; eight of them were upright, four were horizontal, six were turning centers, and two were flexible turning centers. The model CR5116D upright flexible turning cell displayed by Qiqihar No 1 Machine Tool Plant was produced under a technical cooperation with the Dorries Company in the FRG. The machine was equipped with an 8T NC system and an automatic pallet changer (APC). The upright post of the machine bed has a seat type of structure that is connected to the workbench via a fixture cushion. In order to improve the stability of the upright post, the interior of the post was not cleared. The post has a symmetric structure to prevent thermal deformation. The horizontal beam is held onto the post by a 100-mm positioning block to achieve a level 8 positioning. The tool magazine has a capacity of 12 cutters. The workbench has a vertical axle transmission; its main motor has a power of 55 kW, and the speed is controlled in the 2.52-to-315-rpm range. The maximum working diameter is 1,600 mm, the height is 1,000 mm, and the maximum cutting force is 3t; the torsion moment is 18,750 N-m [newton-meters]. This machine will be turned over to the Yongji Electric and Vehicle Plant in Shanxi for use. The Jinan No 1 Machine Tool Plant displayed a CH6144 horizontal flexible turning machine. It is equipped with a chain-type revolutional tool magazine with 16 cutter positions. In addition to the usual turning function, curved surfaces may also be machined on this unit. The machine is equipped with a Fanuc 11TE-A-2 NC system. Automatic loading and unloading of workpieces and automatic machining can be done using the cutter alignment and monitor system, the Flex-1 mechanical hand and the 21-position workpiece-transmission (APC) system. Flexible manufacturing system (FMS) can also be formed with these units.

Each of the 12 MC's on display has its unique features. The model TC500 (TH6150) horizontal MC of the Nanjing Machine Tool Plant is built based on technology imported from Werner-Kolb Company in the FRG. It has a tool magazine capacity of 60, a dual-position interchangeable workbench, and can be incorporated into an FMS. For example, the FMS imported by the Jianglu [3068 7785] Machinery Plant is based on two TC500 main frames. The machine bed is equipped with a Siemens 8ME NC system. Since the main shaft has a precision force-measurement bearing, tool damage and wear may be monitored to manage the service life of the tools. It also has an automatic rinse for the cutting tool and the pallet to ensure the precision of pallet exchange in the 18 seconds of exchange time. The machine bed uses an integral design to increase the stiffness of the main members of the machine bed for cutting at a higher load. The integral design also makes the packaging and shipping more convenient and saves time in installation and tuning. This machine tool has a feed speed of 15 m/min, a cutter-replacement time of 3-5 seconds, and a short auxiliary time; the 6,000 rpm main shaft has a long normal-operation life, suitable for high-efficiency machining of aluminum-alloy casings in the aerospace industry. Although the Nanjing Plant's TC500 is 52 percent made in China, because it was manufactured to completely conform to Werner-Kolb's standards and testing, its internal quality is equivalent to that of the original German unit.

Of the six turning centers on display, two units (CNC-TM400 and CNC-TM420) were designed by the consulting department of the First Branch Office of the Beijing Machine-Tool Institute. They were built by the Taiyuan No 1 Machine Tool Plant and the Anyang Machine Tool Plant, respectively. Another unit, a model CKH7832, was built by the Great Wall Machine Tool Plant. Since most turning centers are similar, we shall describe their features using the model CKH7832 as an example. The CKH7832 turning center is a high-efficiency, high-precision, four-axle, two-gear machine. The upper and lower guide tracks each have a rotatable cutter tray and can machine parts at the same time. Using the self-driven cutters on the cutter frame, together with the C-coordinate (X,C or Z,C), the machine can cut complex surfaces such as the planar surface of an axially symmetric part, or the surfaces of a cam axle or end-face cam. This machine uses a Siemens 3TTE NC system; the X and Z axes are controlled by AC servo motors. The output resolution is 0.2 μm and high-precision turning, milling and boring can be done on this machine. Its price is only about one-half that of a foreign unit.

2. NC Lathes

At this international fair, 26 NC lathes were on display, including 16 economical NC models and 10 intermediate-price units. Together with the eight high-end lathes (turning centers and FMC's), there were a total of 34 machines, accounting for 45.3 percent of the lathes.

In the intermediate-class lathes, the Shenyang Machine Tool Plant No 1 developed the model S1-298 horizontal dual-axle NC lathe for the automobile and home-electric-appliance industries. The two main shafts may be used to machine identical parts with the same or different machine processes, or used to machine two different parts. Using several S1-298 units, a flexible automatic manufacturing line may be formed. For the mass production of parts with a high-precision requirement, the rate of output of this machine is almost twice of that of regular NC lathes. The machine is fitted with a Fanuc-Besk 3TA system. The main shaft has two 22 kW frequency-modulation-governed electric motors. The two turret tool blocks each have eight position tools and the maximum machining diameter and length are respectively 250 and 210 mm. The model CB3640.2MC displayed by Yuxi Machine Tool Plant is an upright dual-axle turret lathe controlled by microcomputer. It is suitable for mass production at an output of 5,000 to 20,000 parts per year. The production rate is 1.5 to 1.8 times of that of two single-axle semiautomatic turret lathes. Since the control system, components and parts of the CB3640.2MC are all made in China, the price is lower and more suitable for enterprises short on cash.

The model NG-CNC 110 longitudinal-cut automatic lathe displayed by the Ningjiang Machine Tool Plant was the first economy model NC lathe produced in China. It is particularly suitable for the machining of small components with a shaft in radios, meters, home electric appliances and military parts. The machine has a five-axis, dual-gear NC system, five stepping motors (to drive the main gearbox and the tool block), and six electromagnetic valves to replace the traditional cam control and avoid the trouble of exchanging or fabricating new cams when the production part is changed.

Since the economy model NC lathe is easy to use, costs less, and is efficient, it is very popular among small and medium enterprises. Based on currently available products, many lathe factories are developing economy-model NC lathes. Of the 16 economy NC lathes on display in CHIMA'90, some used stepping motors to drive the feeding system and others used dc servomotors. In comparison, the former lacks the speed but costs less. The Guangzhou Machine Tool Plant showed some breakthrough in speed on their model CJK6132A lathe; the Z movement can be as fast as 12 m/min. This is because a new GBQ-1 high-speed stepping-motor driver source is used on the CJK6132A machine. (Note: Data shows that, with the GBQ-1 power supply, the model 130BF stepping motor with a static torque of 1.2 kgf-m [kilogram-force-meters] may attain 0.9 kgf-m at 10,400 steps/sec.) The power supply uses a modular structure and separate circuits for smoother running at low speed and to protect against excessive voltage, current, temperature and frequency.

The model CK0630 NC lathe was jointly developed by the Nanjing Technical Institute for Machinery and the Singapore Dungfeng Science and Technology Company. It can not only serve as a training tool for NC technology, but also as a high-precision lathe for machining instrument components. The machining sphericity is 5 μm and the surface finish is Ra 0.8 μm. It was reported that this product is 95 percent domestically made. The precision is one-third higher than that of the British Easiturn lathe but the price is only one-third that of the Easiturn.

3. NC Electromachining Tools

The Chinese machine tool industry is very concerned about the modernization and systemization of machines for tool making. In addition to the electromachining tools displayed in building No 5, the other two buildings also showed a number of advanced accessories for machining molds, such as the MK2945 continuous-locus NC coordinate grinding machine made by the Ningjiang Machine Tool Plant. Among the 33 electromachining tools, 23 units (69.7 percent) were numerically controlled. Data showed that these machines were mostly developed in recent years and are available for mass production. A number of machines have earned the patent rights for their respective types of units. For example, the DK7740 NC electro-discharge machining (EDM) spark cutter of the Beijing Electromachining Machine Tool Plant has been awarded two patents (Nos 87212200 and 89209262.9). The maximum production rate of the DK7740 is 150 mm^2/min, which is three times faster than conventional machines and meets international standards. The model DK7725g NC spark cutter uses a novel wire spooling transmission mechanism (Patent disclosure No CN 2042766U) which improves the stability and extends the service life of the machine. Patents can not only improve the techno-economic benefits but are also a powerful tool for protecting the developer in the economic competition.

The service of the electromachining tools is not limited to the mold manufacture industry; a number of work places have generated substantial economic benefits by developing special machines aimed at solving some key problems in machine manufacture based on the special features of microelectronics and EDM. For example, the Beijing Electromachining Machine Tool Plant has developed a model BD-006 EDM unit for machining small-aperture holes; this machine was developed to solve some of the prevailing problems in machining the injector apertures of diesel engines. Using the EDM method, it takes only 4 minutes to machine four 0.29-mm-diameter injector holes for the 774 diesel engine. This process produces holes meeting the precision and flow specs and is twice as fast as the machine produced by the Raycon Company in the United States. Another example is the BDDC EDM/ultrasound combination

polisher (Patent number 87101455) for super-hard-material instruments; this machine was independently developed by the Beijing Electromachining Institute. Using a combination of ultrasound and high-frequency modulated spark pulses, it can perform precision polishing of super-hard materials such as the wire drawing die made of polycrystalline diamond. Compared with conventional ultrasonic polishers, the composite machine is five times more efficient and saves 50 percent on diamond powder. The machining precision is 1 μm, the surface finish is Ra 0.04 μm, and the price is only one-fifth to one-third that of similar imported units. This machine was awarded the Beijing Invention Award in 1988, the Silver Medal of the Beijing International Invention Prize, and the 1989 Superior Project Award of the State Science Commission. Other machines in this category include the model D3810 planar electrolytic engraving machine developed by the Nantong No 2 Machine Tool Plant and the model D4050 broken tool extractor developed by the Suzhou Electromachining Institute. Although these machines are not numerically controlled, they are very effective and popular among the users.

4. Other NC Machines

Of the 23 milling machines on display, seven (30.4 percent) were NC millers and three of the seven were special-purpose millers. For example, the model QH2-027 NC dual-head, spline-shaft miller exhibited by the Qinghai No 2 Machine Tool Plant is used mainly for the machining of the involute splines at the two ends of the rear bridge shell of heavy motor vehicles. The miller uses a Fanuc-Besk 3MA NC system with specs similar to the West German GF32N machine. In addition, the Yingkou Machine Tool Plant also showed their YK-002 NC system for machining spheres.

Five of the 37 grinding machines displayed were NC units and a number of them were for special applications. The eight H194 NC external end-face round grinding machines of the Shanghai Machine Tool Plant, for example, were developed to turn the fourth and third step shoulders of the second axle in the 1700C-105-B gear box at the Gear Box Plant of the Second Automobile Plant. It employed the Japanese firm Okuma [Machinery Works Ltd.]'s OSP500R-GG NC system. The time to grind the fourth step is 5 minutes and 12 seconds per unit, and 3 minutes and 41 seconds for the third step. The precision is 7 μm for sphericity and cylindricity, 0.014 mm for size dispersion, +/-0.025 mm for axial precision, Ra 0.4 μm for the external spherical surface and Ra 0.8 μm for the end-face. Its performance is similar to that of an imported unit but the price is only about one-fourth of the latter. Another example is the Shaanxi Machine Tool Plant's GZ056 NC grinding machine for main cam shaft necks. This machine is a high-efficiency production grinder developed for turning the main shaft neck of the diesel engine cam shaft (4B and 6B) made by the No 2 Automobile Plant. A Marposs [Italian firm] CNC-E24 NC system is used for controlling four coordinates and meters and the machine can automatically skip gear for grinding the various main shaft neck areas. The accuracy of the machining is 0.01 mm, the cylindricity is 5 μm, the surface finish is Ra 0.63 μm, and the production rate for the cam shaft is 5 minutes and 30 seconds per unit. The price of the machine is only one-half that of a foreign unit. The TYT-3001 NC wire cutter made by the Tianjin Meter and Machine Tool Plant was developed for machining graphite electrodes.

Of the 16 drills, only two were numerically controlled. The ZKJ-5140B economy-model NC upright drill was developed by the Changzhou Machine Tool Plant for machining parts with multiple holes. Although its price is about twice that of a conventional drill, its functions and performance are also much better.

Of the 10 saws, only the GZK4025 fully-automatic band saw was controlled by a microcomputer and can continuously cut 10 parts of different length. The kerf is 1.4 mm and the accuracy is +/-0.2 mm.

Of the nine modular machines, three were numerically controlled. One was the model DHV002 NC modular machine tool with an exchangeable main axle box. Another was the Z351 NC machining cell produced by the No 1 Automobile Special Machine Tool Plant.

The performance efficiency and price of the machine tools on display were considerably higher than those of ordinary machine tools. In order to recover the investment as soon as possible, the machines must be used effectively, which in turn requires the changing of some traditional production management and machine operation habits. For example, the parts should be changed to suit the needs of NC machining. The amount of machining of the blanks should be consistent, the blanks and cutters should be supplied in a timely fashion, there should be a timely feedback of the inspection results of the machined parts, and operators and maintenance personnel should be trained as early as possible so that the malfunctions that are likely to be encountered in the first year after the installation can be taken care of. The industry should therefore regard the proper use of NC machines as a systems engineering task. It should begin with the selection and purchase of the machine taking into account the economic consideration in order to avoid losses due to inappropriate choices of the machine. In this area, the Technical Consulting Office of the No 1 Branch Office, Beijing Machine-Tool Institute, will be able to provide technical assistance to the industry.

5. NC Systems and Software

The 85 NC machines described above each have their own NC and servo systems based on the users' needs on the main frame. The specs of these NC systems will not be repeated here. In the table below, we list the 27 NC systems that were displayed together.

The table shows that the NC systems on display included both high-end products (such as the BS06MF), medium-level systems (such as the BS04G, Fanuc-Besk 6, etc.), and more numerous economic models (such as MNC 862, BS02, etc.). The proportion of economic models is consistent with the demand.

Table I

Developer	Model and type	Utility
Beijing Institute of Machine Tools	Fanuc-Besk 3 NC system	NC lathe and miller
Beijing Institute of Machine Tools	Fanuc-Besk 6 NC system	Machining center, NC lathe and miller
Beijing Institute of Machine Tools	Fanuc-Besk 7 NC system	Machining center, NC lathe and miller
Beijing Institute of Machine Tools	Besk-Fanuc O-mate E-3 NC system	Lathe, miller, and machining center
Beijing Institute of Machine Tools	BS06M 6-axis, 5-gear NC system	Machining center, lathe, miller
Beijing Institute of Machine Tools	BS06MF NC system	Flexible machining cell
Beijing Institute of Machine Tools	BS04M NC system	Machining center, miller
Beijing Institute of Machine Tools	BS04G NC system	High-precision external grinder
Beijing Institute of Machine Tools	BS03 NC system	Economy-model NC lathe
Beijing Institute of Machine Tools	BS02 single-axis NC system	Economy NC drill and turntable
Beijing Institute of Machine Tools	BS01 position NC system	Economy NC lathe
Shanghai Institute of Machine Tools	MTC-1M NC system	Boring and milling machines
Shanghai Institute of Machine Tools	MTC-2M NC system	NC miller, machining centers
Liaoning Precision Instrument Plant	LJ-10 NC system	NC stepped pulse press
Liaoning Precision Instrument Plant	LJ-20 NC system	NC lathe
Beijing Aviation and Space NC Group	MNC862 NC system	Economy NC lathe
Beijing Aviation and Space NC Group	MNC866 NC system	Economy NC lathe
Beijing Aviation and Space NC Group	MNC864 NC system	NC miller, machining center
Xian Micromotor Institute	ZKC2-1A dc NC system	Economy NC lathe
Xian Micromotor Institute	HBKC-2A hybrid stepping-motor-drive NC system	Economy NC lathe
Xian Micromotor Institute	BKX-223-3 NC system	NC miller
Wuxi Machine Tool and Electric Appliance Plant	XNC-1 Machine Tool NC system	Machining center
Shuguang Instrument Plant	YSK-1T NC system	NC lathe
Shenzhen Machine Tool and NC Equipment Plant	SNC-XK-II automatic programming NC system	NC wire cutting machine
No 6 Institute of MMEI	CSE CNC-1 STD bus NC system	
Gansu Polytechnical University	6-coordinate NC system	Gear grinding machine
Electronics Plant, Beijing Industrial University	TPNC-03 dc servomotor NC system	NC lathe, press

In the development and production of NC systems, we continue to adhere to the reform and open policy. For the main frames, advanced foreign NC systems will be imported according to the customer's needs to work with the main frame. We shall continue to strengthen our technical cooperation with foreign countries, and produce high-quality, reliable NC systems such as Fanuc-Besk 3, 6, and 7, and GE MC1. In the meantime, based on our understanding and experience with foreign NC systems, we shall independently develop our own NC systems at different levels. The main-frame manufacturers may select the appropriate NC system using one of the above three approaches based on the customers' needs and the funds available.

In order to broaden the scope of application of Chinese-made NC systems, to enhance the confidence of selecting domestic NC systems, and to serve the production in a sustained manner, many production units for NC systems have strengthened their quality-assurance programs for NC-system production. They have also devoted enough technical resources to provide timely system maintenance for the users and to boost the confidence in Chinese-made systems.

NC systems and servo units developed by the Beijing Institute of Machine Tools have been described in special reports (No 2 of this journal) and will not be repeated here. In the space below we shall select a few systems for description. The MTC-2M system by the Shanghai Machine Tool Plant uses three CPU's in a distributed microcomputer structure to achieve three-axis geared control. The pulse equivalent is 1 μm, the highest speed is 30 m/min, the machining speed is 10 m/min, the graphical display is dynamic with various compensation functions and the input/output is compatible with MTC-1M. The entire system uses generic

components and therefore has a good performance-to-cost ratio. The LJ-20 system of the Liaoning Precision Instrument Plant employs a multiple CPU (80186 chip) structure, modularized hardware and software to allow expansion, and generic components for ease of maintenance. The system is capable of three-gear control at a maximum speed of 15 m/min, has a man-machine interactive menu, English and Chinese dynamic graphics, proportional size and symmetric machining. The LJ-10 system, developed by the Qiqihar No 2 Machine Tool Plant, is used with the step pulse press but is also compatible with a rotatable head press. The highest speed is 40 m/min, the number of pulses is 300 per minute, and the functions are similar to those of the LJ-20. The Beijing Aviation and Aerospace NC Group has developed the MNC862 and the MNC866 systems [see earlier report in JPRS-CST-89-010, 16 May 89, pp 97-98]. The former has an Intel 8086 CPU, medium- and large-scale integrated circuits (LSI), CRT display and a dc servo unit. The maximum speed is 8 m/min, the maximum machining speed is 5 m/min, and the input increment is 0.01 μm. The latter employs an STD bus structure, has an Intel 8088 CPU, and CRT dynamic display. The pulse encoder is used as a testing component to realize semi-closed-loop control. The MNC864 system uses an S-100 bus, a modularized structure, man-machine interactive menu, Chinese character menu, and dynamic graphical display, and has a self-diagnostic capability. It is totally compatible with the Dynapath 10AM system. The TPNC-03 system of Beijing Industrial University has modularized software and hardware, man-machine interaction, and capability for programming while machining.

In addition, control systems developed by the Dalian Modular Machine-Tool Research Institute (DMMTRI) for modular machine tools and automatic [production] lines also employ a modular structure and will accept an internal PC [programmable controller]. The systems have 1-to-5-axis AC servo NC axes and permit multi-axis synchronous machining. They have raised the running rate of machine tools to 85-90 percent.

In the area of software, there are CAD software products developed by the Beijing Institute of Machine Tools and others for the numerical control of boring machines and milling machines. The software consists of the following six parts: 1) a CAD system for the main transmission system and main shaft components, developed in collaboration with Hefei Polytechnical University, 2) a microcomputer intelligent CAD system for machining axially symmetric mechanical parts, 3) a CAD system for the hydraulic system of MC's (the above two items were developed in cooperation with Dalian Science and Engineering University), 4) a CAD system for printed-circuit boards, 5) a CAD system for pneumatic systems, and 6) a CAD system for modular clamps (in cooperation with Beijing College of Mechanical Industrial Management). These software products are user-friendly and practical, and can greatly increase the design quality and operational efficiency when applied to the six areas listed above. These software packages are supported by the hardware environment of an IBM-PC/XT/AT 286 or other compatible CAD workstations. Also on display was the BS-APT automatic programming system for the Fanuc-Besk NC system.

To achieve the management and monitoring of the information flow and materials flow in a flexible manufacturing system (FMS), DMMTRI also has developed an FMS central management and control system. It is built on generic computer software and has a strong FMS resource management and equipment control component. It can simultaneously control seven pieces of equipment with data-communications capability (such as MC's) and equipment without data-communications capability (such as washing machines).

II. Actively Develop Customized Products To Suit the Needs of Technological Reform

Up to this time, China has developed more than 2,000 machine-tool products; while there is a need for improvement, they can basically satisfy the domestic demand. Most urgently needed by the customers today are specialized machine tools, particularly in the priority industry of automobiles. In recent years, a number of enterprises have made use of their technology and have developed many customized products while developing generic new products. Based on the existing YS5120 and Y5132D gear-shaping machines and the YM5132 precision gear-shaping machine, the Changjiang Machine Tool Plant has developed three groups of customized gear-shaping machines (with 32, 13 and 5 models in each group) for automobile plants and gear plants. The YS5120A high-speed gear-shaping machine displayed by the Changjiang Plant has been used in the production of the Riye gear box at the First Automobile Plant. The stroke number is 1050/min, the machining time for a generic automobile gear is less than 3 minutes, and the machining accuracy is a stable level 7. To meet the urgent demand for machining the back gear of the now-imported automobile gear box, the YS5120A work platform is designed to have a tilt angle for machining the inner and outer back gears at an angle up to 10°. Another machine developed for the automobile industry is the model YX9332 high-efficiency inverted gear machine developed by the Nanjing No 2 Machine Tool Plant. Making use of the intermittent gear separation of the part and the back-and-forth motion of the cutter, a PC controls a semiautomatic work cycle to machine 120 teeth per minute; the performance-to-cost ratio is better than that of similar imported units.

Among the grinding machines on display, 32 percent were customized grinders. For example, the model B2-2002 magnetic-head R-surface customized grinder of the Beijing No 2 Machine Tool Plant is capable of an Ra $\leq$ 0.04 μm finish. The B2-097 multi-cutter cutting machine of the same plant has an efficiency three to six times

higher than that of single-cutter machines in machining hard and brittle materials such as quartz. In addition, to serve the automobile and tractor industry, the Wuxi Machine Tool Plant has developed the WX042A grinder for machining the center injector aperture; these are all customized machines based on technological improvements of the users.

At CHIMA'90, customized machines developed by units outside the machine-tool industry were also displayed. Examples are the HS-H series modular machine tools from the Northern Precision Machinery Plant, and the HDM-20A endcap semiautomatic machining units (two to three times more efficient than ordinary machines for machining Y80-Y132 motor endcaps and with a cutter resettability of 3 μm) by the general plant of Hebei Engineering College. In addition, customized machines developed by the users based on their experience of using earlier models were also exhibited. Examples are the Z357 modular machine-tool NC machining cell of the First Automobile Plant and the M6010 cutting-tool grinder of the Nanjing Cutting-Tool Plant.

The Yantai No 2 Machine Tool Plant displayed a C9205-series fully automated geared lathe. The production line built on this machine can return the investment in 2 years and create 300,000 yuan of tax revenue.

The development of customized high-efficiency machines for the users is the responsibility of the machine-tool industry and an important indicator of our ability to adapt to the market. Inspired by the products exhibited at CHIMA'90, the Chinese machine-tool industry (especially major plants with 30 to 40 years of experience) will certainly develop more high-efficiency and sound-quality machine tools to satisfy the technological reform needs of the users.

III. Develop Marketable Products for the International Market

The Chinese machine-tool-building industry has accumulated more than 40 years of experience and has a strong potential for production. During the reform and open period, the plants have actively expanded the domestic market and, based on the needs of the foreign market and the strength of the plants, have strived to develop marketable products for the international market; exports have developed. For example, the Jinan No 1 Machine Tool Plant, co-producer of the Mazak lathe [along with the Japanese firm Mazak], has developed a number of high-quality products and has earned US$10 million of foreign exchange in last year alone, doubling the amount for the year before. A number of popular products on the international market were on display at CHIMA'90. Some were produced in cooperation with foreign companies and sold to foreign countries (such as the lathe produced by the Shanghai Heavy Machinery Plant and the NC divider made by the Yantai Lathe Component Plant), others were multi-function machines developed independently to meet the urgent demand of the international market (such as the Q6001 micro-universal machine made by the Hunan Gaiyang Light Machine Plant), and still others were gap-bed lathes of various specs developed according to foreign customers' needs. In the last category, 11 lathes were on display, accounting for about one-fourth of ordinary lathes.

All the units successful in creating foreign exchange have had the same experience: it takes high quality, timely delivery, strong adaptability, and good service to succeed. The CHIMA'90 exhibit presented the plants with opportunities for selling their products to foreign countries.

IV. Accelerate the Development of Accessories and Auxiliary Components To Satisfy the Demand for Systemization and Versatility

As the customers require more and more of their machines, the demand for high-tech accessories for main frames and better performance will increase. For example, a number of feeding systems have switched from using stepping motors to using DC servomotors for better NC control. To this end, the Beijing Institute of Machine Tools displayed a series of Fanuc-Besk DC servomotors and servo units, and DC main-shaft motors and servos. To improve the efficiency of the MC's (including turning centers), automatic part-changing (APC) devices and mechanical robots (or robot hands) were added; an example is the ZJ-1 industrial robot of the Beijing No 3 Machine Tool Plant. In order to operate FMS's at an optimum load, DMMTRI has developed and displayed their automatic guided vehicle (AGV) for materials flow. It employs a dual-gear velocity differential, DC drive, electromagnetic brake, ultrasonic and mechanical protection, infrared communications, STD industrial monitoring and control, IBM computer communications, a management control, graphical display and malfunction diagnostics. The self-positioning accuracy is +/-5-10 mm, and the mechanical resetting accuracy is +/-1 mm. The machine weight is 1 ton, and the operation is bi-directional, at a speed of 30-50 m/min [see also JPRS-CST-89-008, 29 Mar 89, pp 89-110].

For the purpose of expanding the scope of applications and achieving industrial automation, the Yantai Machine Tool Accessory Plant displayed three models of NC divider heads. Also on display were a number of monitor systems for main frames (such as the GX-10 grating digital micrometer of the No 303 Institute and the two external cutter-alignment devices from the Tianjin Optical Instruments Plant), cutter clamping systems (such as the tool blocks, cutter shanks and carriers developed by the Tianjin NC Machine Component United Company), and automatic lubrication systems (such as the central automatic-lubrication liquid pressure system of the Xiangshan Lubrication Component Plant). These components are very crucial for improving the performance, efficiency and accuracy of the main frames. They are an important aspect of the machine-tool industry structure, and deserve the industry's attention and support.

In order to automate the production process, to improve the surface finish of the machined parts, and to establish civilized production habits, the machines require auxiliary components. For example, the XMW80 horizontal eccentric grinder of the Wuxi Machine Tool Plant is capable of de-burring, polishing and surface finishing. Another example is the DZX003 multi-station wash/rinse and blow-dry machine developed by the Dalian Washing and Filtering Machine Plant; this machine, which can improve the cleanliness of the parts and ensure the accuracy of the machining, is indispensable in an automated production line. It has now attracted a great deal of attention in the production industry.

Whether it is accessories or auxiliary units, they are important components that affect the high-tech development of machine tools. Accessory components especially are an important foundation for the production development task of the industry. We believe that, in the 1990's, China will be able to form even more accessory-component enterprises to meet the demand for generic and special products and to satisfy the domestic and foreign markets in a timely manner.

Instead of describing th displayed machine tools in more detail, the readers are invited to visit the CHIMA'90 exhibits and see for themselves.

FMS Management, Control Software Developed

90FE0074D Dalian ZUHE JICHUANG YU ZIDONGHUA JIAGONG JISHU [MODULAR MACHINE TOOL AND AUTOMATIC MANUFACTURING TECHNIQUE] in Chinese No 3, Mar 90 pp 38-40

[Article by Engineers Geng Ye [5105 0048] and Yang Yuzhong [2799 3768 1813] of the Dalian Modular Machine-Tool Research Institute]

[Text] The flexible manufacturing system (FMS) is a product of modern interdisciplinary technology, and the central computer management and control software for an FMS is one of the most notable and complex technologies.

The Dalian Modular Machine-Tool Research Institute (DMMTRI), under the Ministry of Machine-Building and Electronics Industry (MMEI), has learned from foreign technology and has independently developed the FMS software package ZHS-FMSS-11. The goal is to control an FMS system consisting of a maximum of seven machining centers (MC's) and a rail-guided-cart transportation system to suit general manufacturing plant requirements.

1. Introduction

If only the operation of the FMS is to be controlled, then a programmable controller (PC) would be sufficient. The reason that FMS needs larger computers as the central computer to run the complex software is because of the following FMS requirements:

- Production planning;
- Scheduling the production process;
- Diagnosing and recording system malfunctions;
- Automatic equilization of production when a local malfunction occurs;
- Monitoring and controlling the production process;
- Providing complete man-machine interaction;
- Communicating with plant computers.

The ZHS-FMSS-11 is a software package run on a DEC Micro PDP-11 computer and is capable of performing the tasks listed above.

A typical system supported by the ZHS-FMSS-11 is shown in Figure 1. Although it supports rail-guided small-platform cart transportation systems, it can also support non-rail-guided small-platform cart transportation systems.

In addition to the transportation, the software supports a total of 15 machines, but only seven of the machines can be monitored for the machine and cutter state. The monitored machines (MC's) should have independent communications capability. Non-intelligent machines communicate with the central computer via intelligent surface control devices with the capability of programming and communications.

2. Division of Tasks Between the Central Computer and the Cell Control Computers

Being different from a conventional DNC [direct numerical control] system, the FMS system uses the principle of decentralized control and centralized management. The system consists of a number of cell control computers (e.g., CNC and PC) forming a network with the central computer. The central computer is responsible only for the scheduling and management of the system and the control of the production process is controlled by the cell controllers. This arrangement permits flexibility and provides resistance to local malfunctions.

The tasks for the system unit computers supported by the FMSS-11 are as follows:

- Machine operation logic;
- NC process management;
- Machine malfunction diagnosis;
- Materials flow control;
- Routing optimization of materials flow;
- Man-machine interaction at loading/unloading stations;
- Storage of process-related data;
- Independent communications with host computer;
- Management of cutting tools.

Because a great deal of the work is completed by the cell-control computers, the central computer management is simplified and the stability of the running of the central computer is improved.

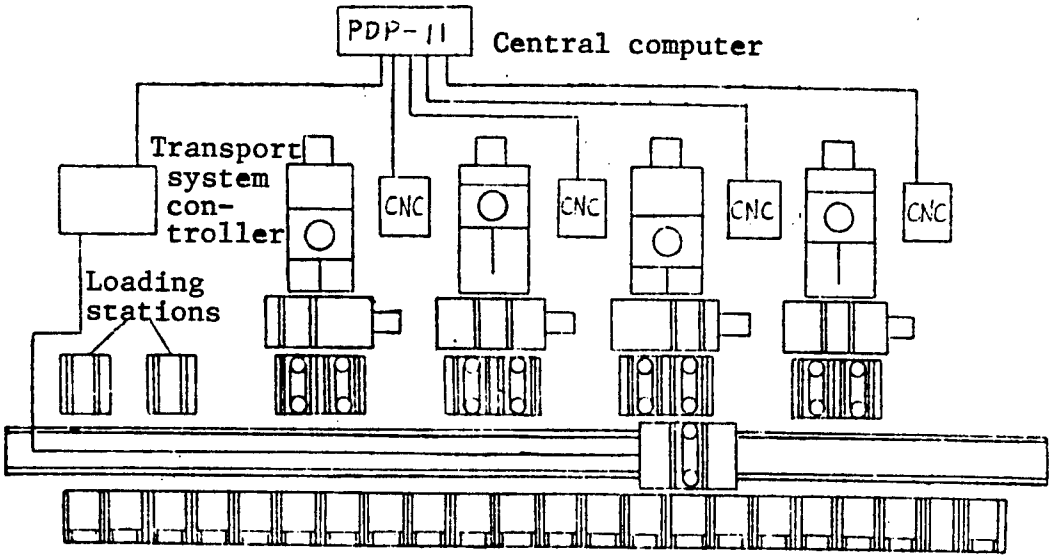

Figure 1. Typical System Structure Supported by ZHS-FMSS-11

3. FMSS-11 Overall Structure

The ZHS-FMSS-11 software package can be run on the Micro PDP-11 using the Micro RSX-11 operating system. The overall structure of the software makes full use of the real-time, multi-task environment of the operating system.

The ZHS-FMSS-11 consists of a number of parallel real-time tasks carried out under the operating system. It may be divided into four main parts (see Figure 2):

(1) Interface Software

The interface software is used for communications between the system and the equipment, between tasks, and between tasks and the operating system.

(2) System Monitoring Software

The system monitoring software is the heart of the FMS; it is responsible for the running, management, monitoring and control of the FMS.

The monitoring software consists of the following main parts:

- Scheduling;
- Machine status monitor;
- Pallet monitor;
- Cutter monitor;
- Production process monitor;
- Machining program monitor;
- Machine utilization condition monitor;
- FMS monitor.

(3) Editing and Display Software

This software provides the man-machine interactive interface. For user convenience, the man-machine interactive menu is written in Chinese.

The editing and display software has these main components:

- Production order editing;
- Part operation plan editing;
- Machine operating condition display and control;
- Process requirements for machining the part;
- Jig data;
- Cutter requirements and data.

These data, given for a specific part, usually do not need changing. They are changed only when the machining job is changed or when new parts are introduced.

Variable data are used mainly for machining instruction, that is, they are the production order data:

- Quantity of parts;
- Method of production;
- Priority in production;
- Delivery data.

The FMS-11 manages the production of the FMS according to the data above.

Another type of operating data in the FMS-11 is the system status data and diagnostic data. These are collected from the systems while the FMS is running; they can be inspected usually using the editing software of the FMSS-11 software.

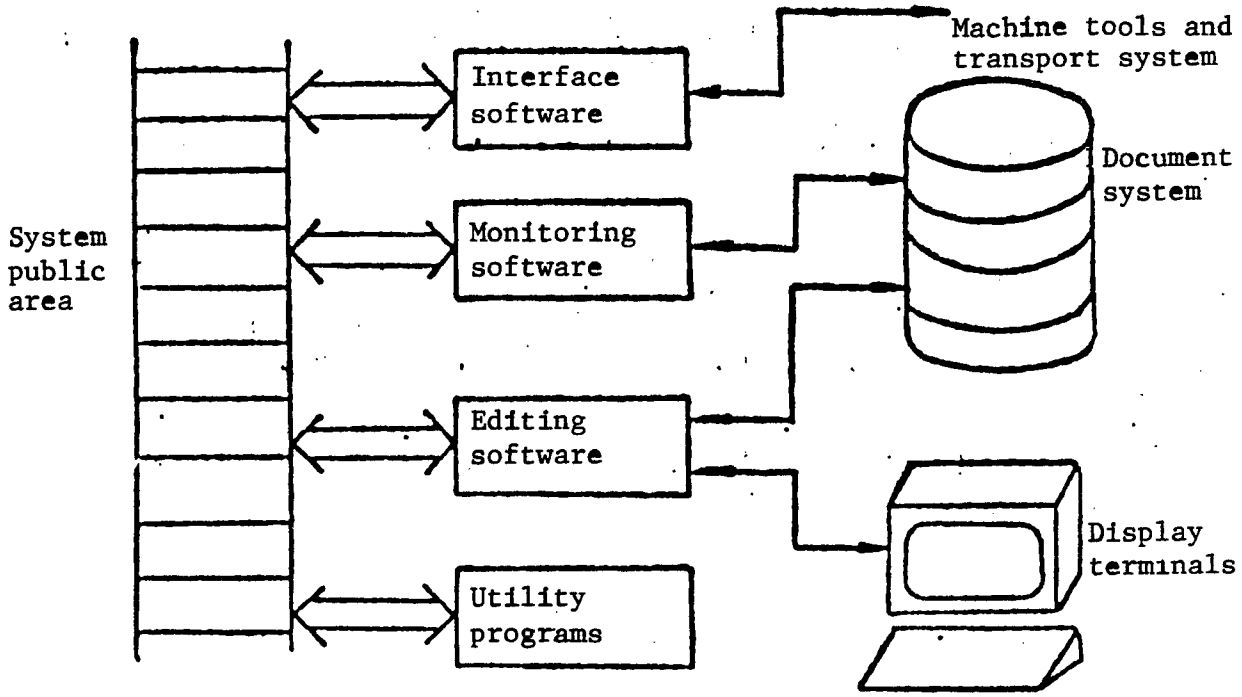

Figure 2. Software Structure of FMSS-11

(4) Utility Program

Some programs are provided for the convenience of the users. These include cross-checking of the data and some programs used for testing the system.

4. Production Operation Scheduling

As stated above, the production scheduling of the FMSS-11 is based on the part operation plan and the production order. The FMSS-11 serves only machining and unloading requests. Before the execution of each step of the machining, the FMSS-11 performs a series of checks to see if the part can be machined in the requested fashion. These checks include:

- Operating condition of the machine;
- The condition of the part;
- Adequacy of the cutter life.

Only after these checks are satisfied, FMSS-11 orders the delivery of the part to the appropriate pallet. If the tests are not satisfied, FMSS-11 will order the machine to perform other executable tasks.

After the completion of the machining step, FMSS-11 then checks the results for acceptance, scrapping, or reworking. The problems revealed in the testing will be recorded and also delivered to the operator.

Higher-priority production missions (orders) are handled first and completed before low-priority tasks. In the scheduling of the materials flow, FMSS-11 only points out the direction of the materials flow; it is the job of the materials transport system to deliver the materials according to the optimized route.

5. Monitoring and Management of Tools and Parts

FMSS-11 maintains all the status records of the tools in the system and updates the records when the tool data change, such as at replacement or at the end of a machine cycle. The FMS operators may inquire or change the tool status data using the editor. They may also change these data with CNC equipment and then transmit these changes to the central computer when the system runs. Since the NC machines in the FMS must often change parts, the parts program must be used properly. Although modern CNC facilities usually have adequate memory to accommodate a number of parts programs, it is still often necessary to transmit the parts program from the high-end computer when the part geometry is complex.

The management of the parts program in FMSS-11 includes:

- Recording and inquiry of status (locked or unlocked);
- Editing of parts program;
- Upward transmission of programs (from machine tool to the central computer);
- Downward transmission of programs (from the central computer to the machine);
- Blocked transmission of complex programs exceeding the NC memory.

The central computer is equipped with a 10MB Winchester disk as a program memory; punched paper tape is generally not used.

6. Treatment of Errors and Local Malfunctions

Since the units in the FMS have their own independent diagnostic and malfunction handling ability, the FMSS-11 is responsible only for the recording and reporting of the error messages and to equilize the scheduling.

The responses include:

- Registering and recording the alarm for tool damage;
- Program locking when a machine malfunctions;
- Diagnosing and recording communications errors;
- Automatic adjustment of the production when a machine malfunctions;
- Restoring data when the system collapses.

The FMSS-11 system has sufficient file memory for recording any error messages of the system for later analysis and evaluation.

7. Conclusion

As a practical software package, ZHS-FMSS-11 can completely satisfy the needs of the FMS system of a small-to-medium-size plant. This software has been thoroughly tested on an FMS physical simulation system [see JPRS-CST-88-020, 28 Sep 88, pp 44-45, as well as article below], and has proven to be reliable and stable.

Currently the software is run on the Micro PDP-11/23; the speed is somewhat slow and the number of machines is also limited by the operating system. In the next phase of the work, we shall improve the performance of the software in anticipation of the continuous development and advancement of China's machining industry.

FMS Physical Simulation System Developed

90FE0074E Dalian ZUHE JICHUANG YU ZIDONGHUA JIAGONG JISHU [MODULAR MACHINE TOOL AND AUTOMATIC MANUFACTURING TECHNIQUE] in Chinese No 3, Mar 90 pp 41-43, 46

[Article by Engineers Yang Yuzhong [2799 3768 1813] and Geng Ye [5105 0048] of the Dalian Modular Machine-Tool Research Institute (DMMTRI)]

[Text] The management and control software of a flexible manufacturing system (FMS)—usually referred to as the FMS host or node software—is an important part of the FMS system. To develop and test software is a complicated task; especially, to test software and analyze its feasibility is very difficult before the actual hardware system is built. Even after the real system is built, it is often difficult and uneconomical to test the software entirely on the real system. It is therefore quite necessary to use some auxiliary method such as physical simulation or computer simulation to test newly developed FMS host software and verify its feasibility.

In physical simulation, models of the FMS are built; the function of the FMS host software may be demonstrated very realistically. This has certain advantages that cannot be realized in purely numerical simulations. Many foreign universities and research institutes have built their own physical simulation systems.

In order to test management and control software for the FMS host at the Beijing Institute of Machine Tools, we [i.e., DMMTRI] built a physical simulation system in 1987, as shown in Figure 1. After 2 years of operation, the system performance and reliability have all achieved the targets. Experience has shown that the FMS physical simulation system is a powerful tool for developing and testing FMS host software.

1. Components of the Physical Simulation System

Figure 2 shows that the physical simulation system consists of a linear rail-guided cart, four machine tools, two loading/unloading workstations, 22 pallets, 22 pallet buffer stations, five TP805 microcomputers, and the electrical system for communications and control. The entire system is mounted on a 5-m x 2.2-m workbench. The components may be rearranged for a different layout. The system is suitable for testing the host software for an FMS based on linear rail-guided carts. The host computer in Figure 2 refers to the computer that will run the host software of the FMS.

The rail-guided cart consists of the walk mechanism, the positioning mechanism and the pallet-exchange mechanism. The cart can move to the various buffer stations, loading stations and the pallet-exchange mechanisms on the rail, and can accurately exchange the pallets. The drive motor is a constant-torque motor and drives the cart after a speed change. The speed control is achieved by transforming the voltage. The positioning mechanism uses a contactless switch for relative position memory; the location is set accurately by mechanical means. When the cart receives an instruction to go to a certain position, the relative distance is first computed and the contactless switch is used to check the distance traveled and to determine if the cart has arrived at the destination. When the switch detects the destination, the cart stops and an electromagnetic magnet pushes a conical pin into a positioning block on the pallet to establish the accurate position. The pallet-exchange mechanism uses a chain-and-gear-wheel mechanism. There is a high lever and two low levers on the chain and the cart has four contactless switches. The levers on the chain, driven by an electromagnet, can perform the following motions: pull the pallet from the buffer station, the loading station, or the pallet-exchange mechanism onto the cart, or push the pallet from the cart onto the buffer station, the loading station, or the exchange mechanism.

The simulation machine consists of three movable coordinates X, Y, and Z, two pallet-exchange mechanisms, and a rotatable main shaft. The chain and gear on the

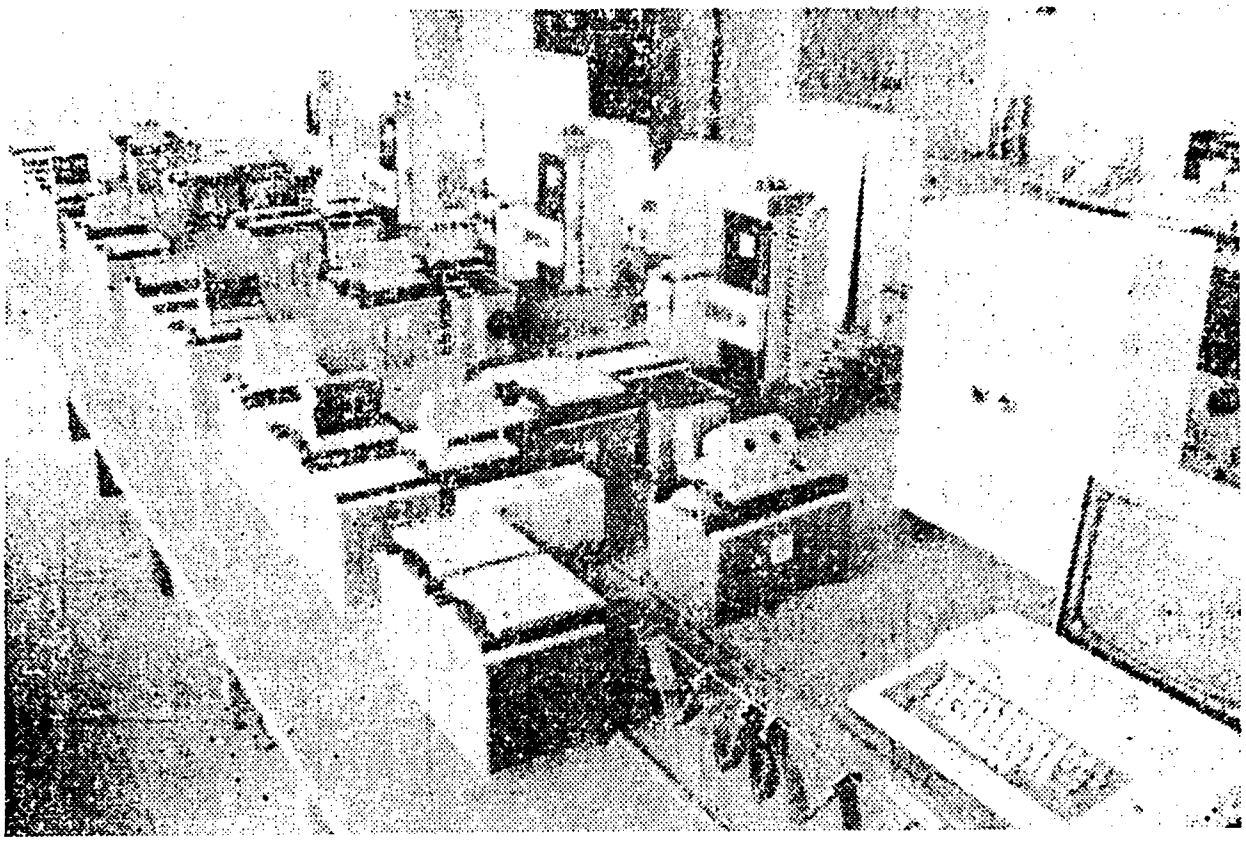

Figure 1. The FMS Physical Simulation System

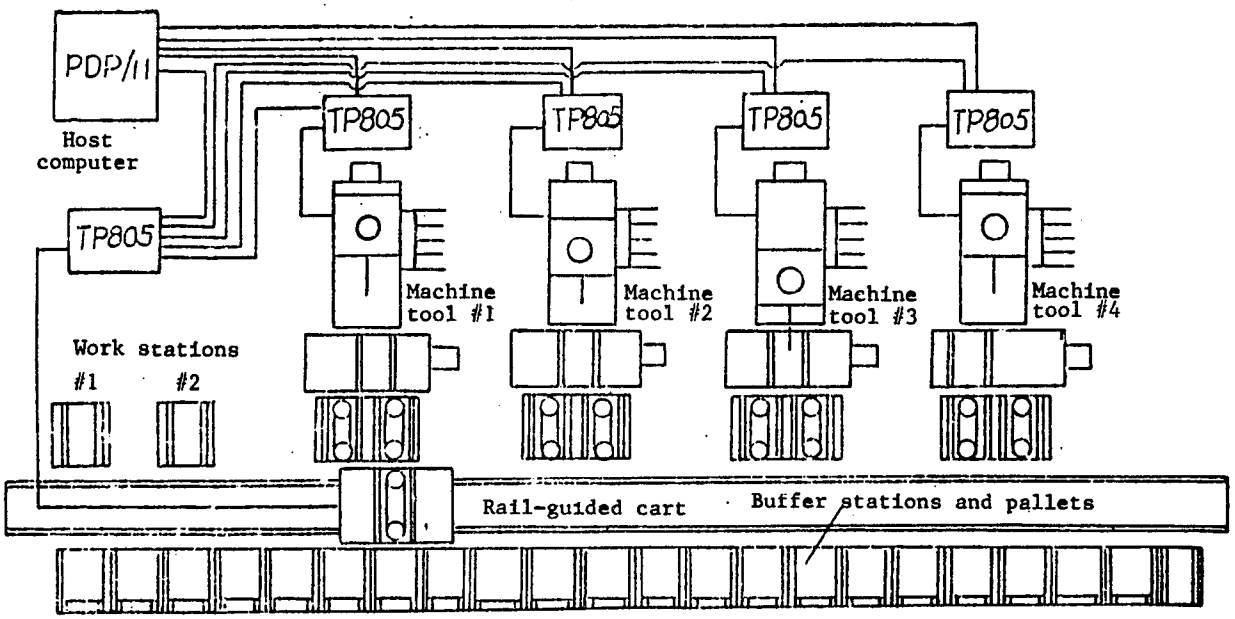

Figure 2. Layout of the Physical Simulation System

exchange mechanism can push the pallet onto or from the cart. The machine tool can only move but cannot do the actual machining.

The buffer stations and the loading stations are used only for storing the pallets and the parts; they cannot move on their own.

The system uses five TP805 microcomputers as the simulation controllers. One of them is used as a materials flow system and for simulated ground control, and the other four are used for the four simulated CNC machines. The control systems are shown in Figure 3.

The TP805 microcomputers communicate with the central computer through an RS232 interface; communications protocols can be programmed as needed.

Because the system has communications capability, the data flow of the FMS system is realized. The materials flow is realized by the carts and pallet-exchange mechanism. The machine can simulate the various movements in production and other system functions may also be installed in the simulation software of the TP805 computers. The physical simulation system can therefore simulate the hardware environment of the FMS host software.

2. Simulation of the Transport System and the Control of the Model

The transport system is an important part of the physical simulation system because it demonstrates the materials flow of the system.

In the design and control of the transport system, we completely simulated the information exchange, queuing, process optimization and communications between the machines. The operation of the simulation system is quite realistic.

2.1 Simulation of the Loading Station

The loading station is treated as a device in the software and the operation of the loading station is similar to that of the machine. Since many operations require human participation, the man-machine interface is very important. The simulation provides screen display and uses the keyboard to replace the buttons. The operator may call up the pallet on the workstation model and unload the pallet. Figure 4 shows a screen display of the simulation system.

2.2 Simulation and Control of the Cart System

The operation of the cart motion is done with the TP805 microcomputers. The route and mission of the cart are determined by the FMS host software and the cart-control software. The cart system maintains an internal instruction queue and commands coming from the outside (from the FMS host or from the keyboard) are placed at the end of the queue. The instructions are executed from the front of the queue. When an instruction calls for sending the pallet to a buffer station, the cart system will optimize this instruction, that is, search through the queue and find out if there are instructions to send the pallet to other devices. If such an instruction exists, then the latter command will be executed and the former will be passed over. After a command is executed, the cart system automatically readjusts the command queue.

The cart system also maintains another table for the pallet position and status. Since a machine may be busy with two or more pallets at the same time, the cart

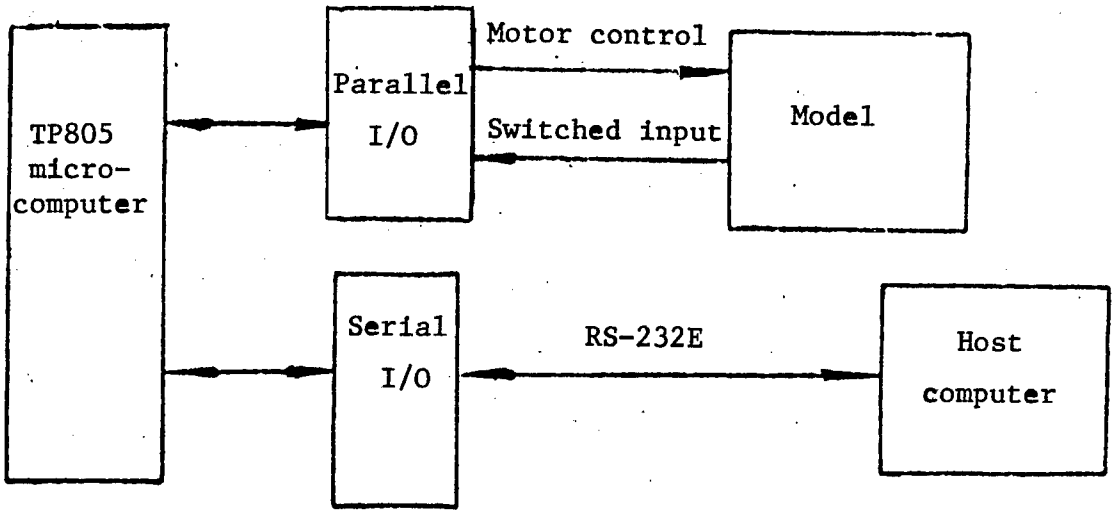

Figure 3. The Control Systems

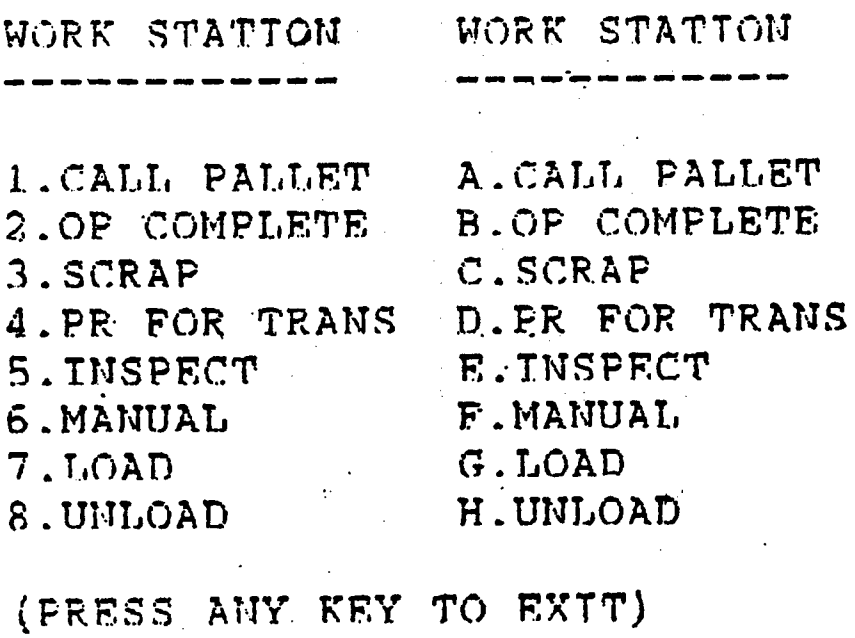

Figure 4. Screen Display of the Simulation System

system must remember the current position of each pallet. The transport system is capable of reporting to the FMS host the pallet position changes and status changes of the carts and the workstations.

3. Simulation and Model Control of the Machines

Since the FMS host software does not control the actual movements of the machines, the simulation of the machines is concentrated mainly on the information exchange, pallet exchange, and machining time.

At the request of the machine, the cart may move the part to be machined to the pallet-exchange position. If the machine is ready to work on the part, then the exchange mechanism will move the pallet onto the machine, which in turn machines the part according to the programmed time and the exchange mechanism then pulls the pallet down.

Establishing information exchange with the host computer is the key to the testing and development of the FMS software. The machine system is capable of total and reliable communications with the FMS host; this information includes:

(1) Machine status report;
(2) Cutter status report;
(3) Work request;
(4) Unloading request and part status report;
(5) Receipt and processing of messages from the host computer.

With the intervention of the operator, the machine system can also scrap a part, rework a part, and set machine error. The machine may be in the automated state or in the manual state.

4. Conclusion

Actual operation shows that the physical simulation system may be used in the following areas:

(1) In the development of the FMS host software, the simulation system may be used for the independent tuning of software modules, such as the communications function or the pallet scheduling function.

(2) After the FMS host software is completed, the entire host software may be run on the simulation system to verify its operation and to perfect its program.

(3) The simulation system may be used to simulate the machining time and routing of various parts so that the correct machining procedures are built into the FMS.

(4) Before the FMS is built, the main computer management personnel may be trained with the simulation system to obtain the same benefits as training on a real system.

CNC System Developed for Six-Axis, Four-Link Hobbing Machine

90P60070A Beijing KEJI RIBAO [SCIENCE AND TECHNOLOGY DAILY] in Chinese 14 May 90 p 1

[Article by Cao Yongan [2580 3057 1344]: "Six-Axis, Four-Link Hobbing Machine Computer Numerical Control System Developed"]

[Summary] Lanzhou, 13 May (XINHUA)—Completion of one of the key State Seventh 5-Year Plan projects—the development of a six-axis, four-link hobbing machine computer numerical control (CNC) system—has been realized in Lanzhou. This key technology represents a further step forward in the realization of

flexible manufacturing, and is on a par with the world state-of-the-art.

According to an expert analysis, this technology has been mastered by only a very small number of countries. The system, developed by Gansu Polytechnical University professor Wang Mingde [3769 2494 1795], has man-machine interactive dialog with menu screens, automatic programming, and a graphics monitoring display. It has proven effective in providing the data accuracy necessary for machining ellipsoidal gears—a part heretofore notoriously difficult to machine.

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